CHAPTER FOURTEEN

FACTORY OF THE FUTURE

CONTENTS

FACTORY OF THE FUTURE

OBJECTIVE

Planning for system production is driven primarily by the existing and expected near term (less than 5 year) improvements in factory technology. Consideration of the longer term factory technologies may be necessary especially for those programs in Concept Exploration /Definition or Concept Demonstration/Validation. This chapter describes the environment and major influences operating to change the nature and role of the factory. The primary areas of change in the factory of the future are described and a brief summary of the current status is discussed.

INTRODUCTION

The transition from hand crafted products to mechanization of the factory was seen as a significant industrial accomplishment during World War II. Since then, more and better machines have contributed to improved precision and a better quality, lower cost product. Mechanization has continued to play a leading role in the industrial economy but "modernization" has had an even greater impact as the emerging computer technology has been applied to industrial equipment. For instance, mechanical tool control devices, such as special cams for automatic lathes, have been replaced by direct numerical controls which eliminate the need for a special set of cams for each new part configuration. This innovation not only eliminated a costly tool component but drastically reduced set-up time for each new part. While maintaining the same capability to accurately reproduce many parts, greater freedom for part variation was provided. With machine control centered in a computer program, a relatively minor computer program change is needed to affect a change in part configuration compared to two to three hours previously required to change cams.

Similar examples can be cited for equipment used in a variety of industrial processes where computer control or computer aided control systems have been incorporated in new equipment designs for more efficient performance.

No single technological advance will have as great an impact on industry during the 20th Century as computer aided design/computer aided manufacturing (CAD/CAM). The National Science Foundation has stated that, "CAD/CAM has more potential to improve productivity than any technological development since electricity."

The factory of the future will be a totally integrated business and manufacturing system. The system will include modular subsystems for managing all functions from marketing to product shipment. A fully integrated system will provide business planning and support including customer order processing, finished goods inventory management; engineering design including computer assisted drafting, design and simulation; manufacturing planning including process planning, materials planning, inventory record control, order scheduling, dispatching and machine loading control, and computer controlled machine operation, testing and process automation.

Technologically we are at the dawn of another industrial revolution brought about by the inexpensive computing power available through today's electronic technology. Computer aided design (CAD) and computer aided manufacturing (CAM) are the applications of this computing power to manufacturing and the selection of manufacturing processes driven by this technology.

To date, no one has implemented a completely integrated CAD/CAM system. However, each of the elements and cells which collectively make up a plant and the communication and control system modules for directing plant operation have been successfully implemented in today's industry. Even though a completely automated factory does not now exist, all the essential components exist and we can describe the factory of the future as a collection of computerized or computer aided subsystems capable of essentially no direct labor operation.

FACTORY TECHNOLOGY

The extent of automation will vary widely from individually automated numerical control (NC) machine tools to a completely integrated computer aided manufacturing (ICAM) system. The size and type of the business, the manufacturing methods employed, and the economic state of affairs are some of the factors that dictate the level of automation appropriate for each industry or company. The trend of manufacturing in this country is "written on the wall" when we see machine tools which operate entirely free of operator intervention. And, what is more amazing, perform a great variety of tasks taking their instructions from computer generated design specifications.

Factory automation includes the use of such equipment as: 1) numerical control machines, 2) transfer machines, 3) robots, 4) automated warehouse systems, and 5) material handling devices (hardware systems for processing, handling, or storing factory products). Japan leads the world today in the use of automated manufacturing.

In order to visualize the factory of the future, let's examine each of the components of automation, the element, the cell, and automation at the plant level:

The elemental level or work center is the basic unit of automation and involves two components. These are the process mechanization component and its corresponding information component. A computer-based automation element always includes both the process mechanization component and the informational component.

The next higher level of automation is a cell. The cell provides automation for a functional segment of a plant consisting of a group of machines or work stations which perform similar operations or a series of operations.

The highest order of automation is at the plant level. Automation at the plant level includes computerized management of any number of automated cells.

Automated Factory Structure

The element level is where the basic concept of automation begins. When a machine control unit does electronically what an operator has been doing visually, then machine instructions can be computer directed. At the cell level, full machine control has been achieved for a wide range of machines, enabling them to be controlled and monitored much closer than by human control. For instance, adaptive control units (for which fixed speeds and feeds are not programmed) utilize feedback sensors to optimize operational conditions by sensing pressure conditions at a cutting tool position and automatically adjusting feeds and speeds within a desired range. The control will also reduce feeds and speeds if adverse conditions are met. This permits operation to optimize cutter life and/or lower machining cost. Adaptive controls can be applied to sense loads, temperature or other phenomena. Control systems are not limited in the number of control actions which can be managed. They are used to: turn on a machine, check initial condition, through to even signaling a malfunction and indicating the location of the problem. In turn, a number of elements can be interconnected (i.e.. work centers) to form a cell where many machines perform a variety of operations.

The cell arrangement may be sequential, where parts flow along in the manner of an assembly line; complementary machines, performing similar operations on a variety of parts; or machine groups dedicated to processing a special material, such as in a plastic molding shop. Work flow to, through and from the cells, and a continuous monitoring of parts for each order is maintained according to a predetermined schedule. A cell can be utilized to produce a specific part in a dedicated operation or to produce several different parts. A family of parts or similarly shaped parts can be grouped for effective machine utilization. Radically different shape parts also can be produced, but maximum productivity and operating efficiency are obtained when similar parts are collected on a job order to minimize set-ups and tooling changeovers.

Interconnecting a number of cells through a computer network will provide the highest level of automation. Support services such as inventory control, quality control records, special test requirements and performance records for any and all work stations will be available as a record of the automated factory's operation.

Every part of the factory of the future is here now. An example of a computer integrated manufacturing system illustrates the versatility of automation. Computer control of one plant's gear machining cell has, for over ten years, been used to monitor machine operations with an outstanding record of machine utilization. One important feature is the diagnostic capability designed into the system. In the event of a machine malfunction, which requires operator attention, the maintenance operator (not a machine operator) is alerted and a video screen display in the area indicates the difficulty and displays the appropriate maintenance procedure for corrective action. The result has been more efficient maintenance and an outstanding record of machine utilization.

Flexible Manufacturing Systems

Flexible manufacturing systems (FMS) started with attempts to combine several numerically controlled machine tools with an automated materials handling system all operating under computer control. More current applications of FMS handle palletized workpieces of different types which randomly travel among and are processed by a group of programmable, multi purpose machine tools and work stations. Many of these applications include automated inspection, adaptive control systems, sensors and vision or other tactile information processing equipment.

As the integration of FMS continues, future applications will feature a number of cells operating under a general command computer, buffered but some intermediate work in process inventory by operating with a high degree of synchronization among the cells. While the introduction of FMS in the US has been slow (estimate of 4 in 1975 to 46 in 1985), a recent forecast by the Yankee Group estimates that this could grow to 280 installations by 1990.

Expert Systems

Expert systems are computer based decision or analysis aids which apply rules developed by drawing on the knowledge base of experts in a specific field. The knowledge base is structured in rules or representations which can assist the designer in developing and specifying a design which will be well adapted to the manufacturing environment. Current research is focusing on the development of a theory and practice for mechanical and electrical design and selection of manufacturing processes. Some of this research is being fostered under the AF Concurrent Design program, but the majority of it is sponsored by the commercial industry. Some of the major objectives of the research are to develop expert systems to:

- Do on-line evaluation of designs for manufacturing demands
- Support manufacturing process planning
- Utilize new languages for the representation of manufacturing knowledge.

These systems are also being explored to develop the capability to analyze the logistics implications of the design and support the design of the logistics support elements.

Machine Vision and Tactile Sensing

Current applications of vision systems are primarily for the control of manipulation tasks such as sorting, assembly, welding and riveting. Machine vision has also been applied to inspection, evaluating characteristics such as dimensions, color, and orientation. Research is currently being pursued to expand the capability of vision system primarily in the speed of pattern discrimination and the ability to discriminate shading, texture, color and motion. The keys improved performance of vision systems appear to be in parallel processing and application of Very Large Scale Integrated Circuit (VHSIC) technologies to this task. The development and economic application of machine vision may well be the prerequisite to achieving the full benefits of truly computer integrated fifth generation factory automation.

Communication Links

Communication links are essential in an automated plant to assure that coordinated operations run according to an overall plan. Equally important are the communications which link manufacturing with its related business functions. Examination of the factory of the future by its functions (Figure 14-1) illustrates the variety of information processing activities which must be provided to successfully implement a fully integrated production system. The traditional distinction between product design and manufacturing engineering will be minimal or no longer exist. The truly computer integrated factory of the future will provide for the output of one system to serve as the input to another. For example, the business planning and support provided by the sales force relating to product descriptions serves as an input to the engineering design function. If the product contains previously designed components, a computer assisted drafting system would output the engineering drawing information to the Bill of Materials Processor and to Manufacturing Process Planning for Order Scheduling. If the product description contains new features or new components, the description would serve as input to a CAD system where interactive graphics could be used as a design technique to produce engineering and manufacturing information. A CAM system interacting with CAD would provide the full compliment of functions to process the ordered product through the system.

BUSINESS PLANNING AND SUPPORT

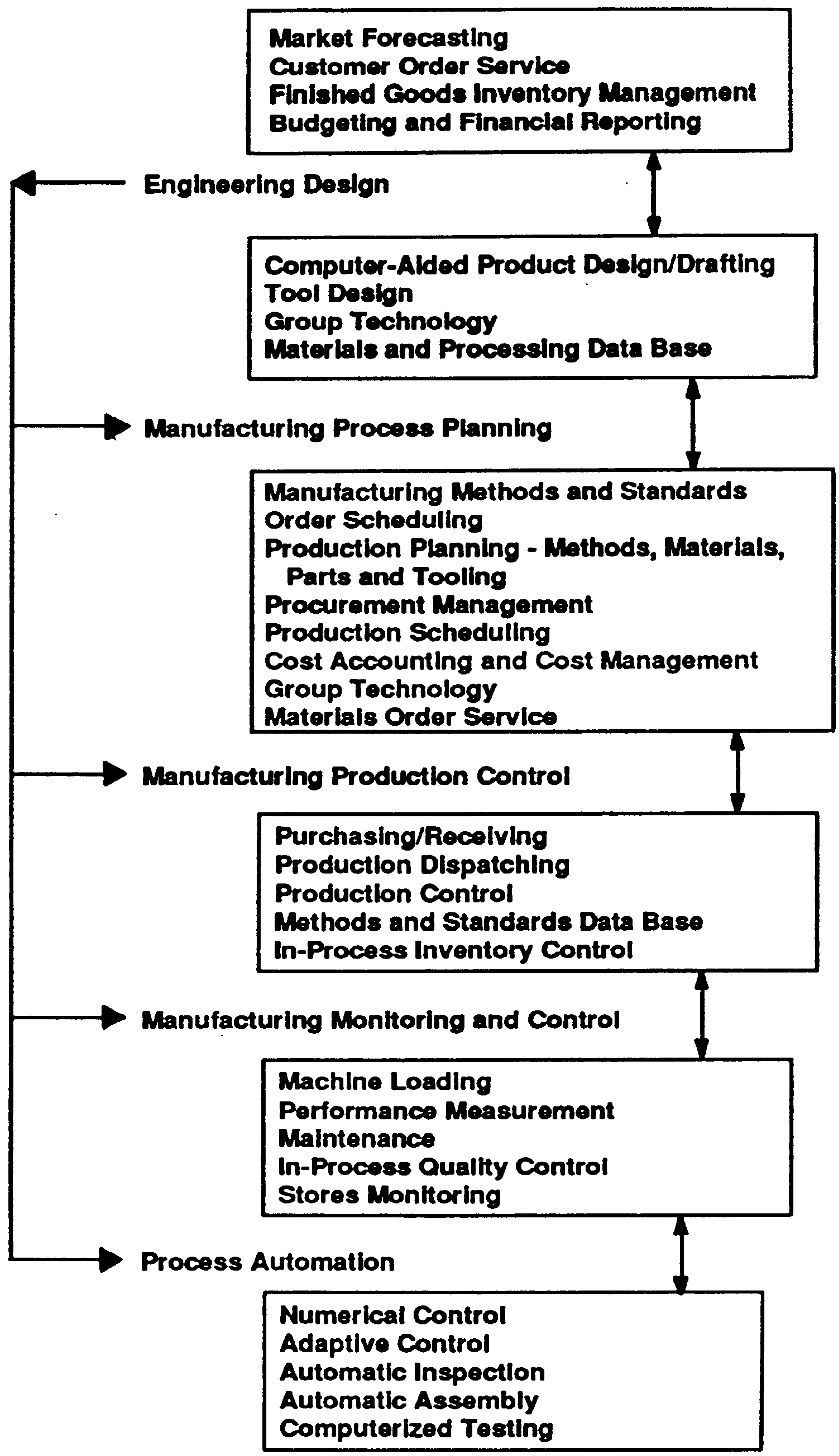

Figure 14-1 Integrated Manufacturing System

Changing Role of the Manufacturing Engineer

In 1988, A.T. Kearney, Inc. conducted a study commissioned by the Society of Manufacturing Engineers to explore the future role of the manufacturing engineer. This study concluded that the manufacturing engineer of the year 2000 will be faced with a new set of challenges in the form of:

- An environment exploding in scope
- Multiple roles
- Advanced tools
- Changed work emphasis

The dominant causes of the changes in the challenges faced by the manufacturing engineer arise from:

- Increased product sophistication and variation
- A global manufacturing environment
- A multitude of social and economic changes

The role of the manufacturing engineer will also change dramatically. The A.T. Kearney study indicates that the three primary roles that manufacturing engineers will play by the year 2000 are:

- Operations integrator
- Manufacturing strategist
- Technical specialist

To meet these roles, the manufacturing engineer will have at their disposal much more advanced tools including communications devices, expert systems and other software. The emphasis on how work will be accomplished will be far different with more importance being placed on the human aspects of production and less on the technical. Teamwork rather than individual effort will be the key to success.

Major changes in the basic and continuing education of the manufacturing engineer will be required to respond effectively to these major challenges.

Future Expectations

In the future, the truly integrated manufacturing system will provide assistance to all business functions from order entry to product shipment. Productivity in developing and producing affordable and supportable weapons is the “New Era” of the 1990s and beyond. CAD and CAM have taken the first steps. The advancing computer and data systems technologies (data base management, data distributed networks, distributed processing) afford the means to move toward the integrated system with its attendant benefits. The DOD and its supporting industry have taken some initial steps but there is still a long way to go.

A market study published late in 1988 by Automation Research Corp of Medfield, MA forecasts that the price of factory automation systems is reducing. The study, titled Factory Management Systems: Cell, Area, and Factory Levels, reports that the number of manufacturing software tools available today is on the rise, making it more cost effective for software developers and end-users to develop specialized manufacturing software. As a result we can expect to see more new and affordable manufacturing packages over the next few years.

According to this study, the trend has already begun to have an impact. For example, while the US market for factory management software was worth more than $475 million 1987, these shipments are projected to grow at an average annual rate of nearly 12% through 1992, when they will rise to more than $830 million. About $525 millionworth of factory management software is expected to be shipped this year alone.

The study also groups manufacturing software into seven categories and predicts growth rates for each. Some of these are:

- Cell Control: About $16 million worth was shipped in 1987, and more than $80 million worth will be shipped in 1992.

- Quality Control: About $21 million worth was shipped in 1987, and more than $34 million worth will be shipped 1992.

- Production Management and Scheduling: Around $35 million worth was shipped in 1987, and nearly $120 million worth will be shipped in 1992.

- Factory Simulation: About $25 million worth was published in 1987, and $90 million worth will be shipped in 1992.

Significant US Government effort is being applied to developing manufacturing communications tools and systems.

THE HUMAN ELEMENT

A major environmental characteristic of the factory of the future is the changing nature and role of the workforce. As the "baby boom" of the 50's and 60's is replaced by the "baby bust" generation of the 70's, the supply of new workers entering the job market will drop substantially. This employee shortage is already impacting the fast food industry with its heavy reliance on part time high school and college age employees. As this shortage begins to impact the industrial entry process, major changes in the role of the employee will follow. In addition to the obvious impact of increasing wages and salaries as industry competes for a decreasing pool of talent, the relationship of the firm and the worker will change. Greater emphasis will be placed by industry on developing long term employment relationships. Education and training will be provided by industry.

The need for this education and training will be driven by two forces. First, success in the future factory will be driven by industry's success in harnessing the creative power of the worker. As John Naisbit describes it in "Megatrends" "The more technology around us, the more the need for human touch." Technology raises the level of knowledge required. In addition, the world class competitors have learned that providing all employees the opportunity to contribute to decision making is critical to success. Mr. Rene McPherson, Chairman of the Dana Corporation, has said: "Until we believe that the expert in any particular job is most often the person performing it, we shall forever limit the potential of that person in terms of both his contribution to the organization and his personal development . . . Within a 25 square foot area, nobody knows more about how to operate a machine, maximize its output, improve its quality, optimize the material flow, and keep it operating efficiently than to the machine operators, material handlers and maintenance people responsible for it." This philosophy is the basis for employee involvement programs such as quality circles, one of the major contributors to the success of Japanese industry.

The second force motivating industry to increase education and training is the perceived performance of American schools. As reported in the July 4, 1988 issue of Fortune, "In the United States, 30 percent of all high school students - one million teenagers each year - drop out before graduating. Most are virtually unemployable. And of those who do graduate, many do not have the problem-solving skills necessary to function in an increasingly complex information society." Industry is reacting by increasing support to and involvement in public education and by adding education to their internal employee development programs.

The forces of much management attention in the factory of the future will be on the human contribution to progress. Motivating, educating and empowering the full work force combined with application of new manufacturing and information technologies will be critical elements in factory success.

FACTORY NETWORKS

Digital Equipment Corporation was one of the first computer vendors to perceive then need for enterprise-wide communications in corporate America. To communicate this perception Digital came up with the slogan "The network is the system." At about the same time, Sun Microsystems announced that it too saw a networked future and, further, that in its vision, "The network is the computer." IBM has adapted its System Network

Architecture (SNA) design into the peer-to-peer System Application Architecture (SAA) system. Chairman John Akers has stated that “transparent access to remote data” is now required, and is among the company’s top three R&D priorities.

A key question currently being addressed is whether the order-entry and control systems are the end point of networking for corporate America? What will all the new networks of the 1990s connect to, and what will they do?

Manufacturing managers have come to realize that one of the key sources of their productivity woes is not with their inability to automate the manufacturing process but with their link between what’s designed and what’s manufactured. Getting 10% improvement our of a machining station may cost a lot more than motivating engineers to design components using common parts and getting engineers to design parts that are easy to manufacture, assemble, and service.

This is no easy task. The design that feeds manufacturing has traditionally been a stand-alone function, discrete even from the engineering analysis that determines whether a part will actually work. And that’s a traditionally separate activity from the engineering that determines who the manufacturing floor should tool up to make the parts.

The ENE 88i (Enterprise Networking Event ’88 International) conference strongly indicated that the next generation of networks-the open generation built on Open Systems Interconnection (OSI) standards will revolutionize the production of goods worldwide. These networks will lead to and from all factory floor around the world.

The factory floor is where the big payoffs will be, the places where more human knowledge will be turned into more useful products than anywhere else. But the factory floors will not be where they used to be; in fact, they won’t even be what they used to be. Manufacturing Automation Protocol/Technical and Office Protocol (MAP/TOP) will change everything. From now on, economic value will be added in the MAP/TOP networks themselves, not on any traditional factory floors.

The MAP/TOP duo is the heart of all preproduction technologies in the next industrial age now taking shape worldwide, the so-called CIM (computer-integrated manufacturing) age. MAP and TOP are two distinct networking schemes, but, by deliberate design, they work together and share five layers (layers 6, 5, 4, 3, and 2) of the seven-layer OSI architecture. (See Figure 14-2).

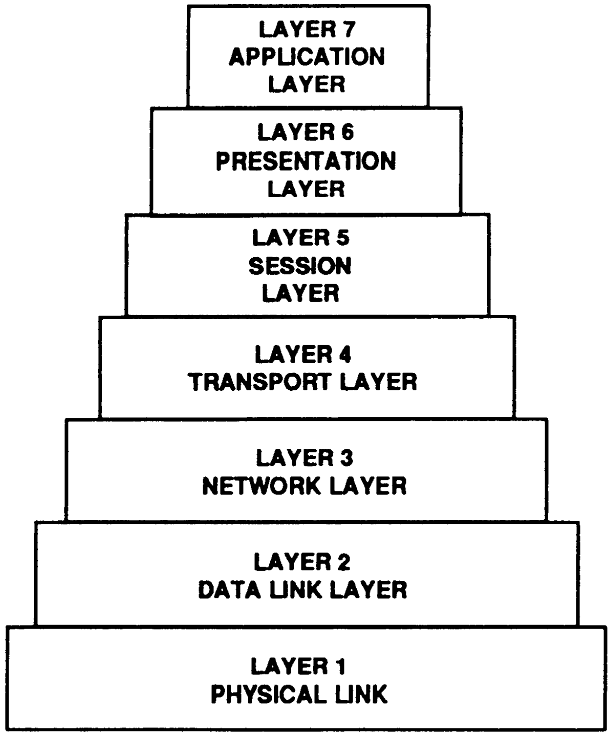

Figure 14-2 Open Systems Interconnection Model

TOP is aimed at engineering and business activities; its CIM partner, MAP, is designed to tie into and control activities on the factory floor. To best perform their diverse roles, MAP and TOP remain distinct and specialized at OSI layers 7 (the application layer) and 1 (the physical layer).

Already, Boeing, one of the prime movers behind TOP, uses integrated design/build teams instead of design and build teams as before. Boeing refers to its MAP/TOP networks as "enhanced information systems" and places them at the core of its CIM effort. General Motors, a major supporter of MAP, currently has 20 facilities under or going under MAP.

Worldwide, there are now about 100 known installations using MAP and about a dozen using TOP. Virtually all these installations are world-class competitors, including the likes of BMW, Deere & Company, British Aerospace, Ford, Eastman Kodak, Du Pont and Lockheed. In addition, the U.S. Government has issued its Government OSI Profile (GOSIP) requiring OSI standards in the 1990s. In GOSIP, the government has virtually committed its $300 billion per year defense procurement budgets to companies that favor MAP/TOP systems.

The major CIM leaders in Europe are one or two years ahead of their U.S. counterparts. And the Japanese are somewhere in between the leaders in Europe and the United States.

ENE 88i provided demonstrations of MAP/TOP 3.0, the latest version of that combined preproduction technology. Applications had been previously tested in the United States or in Europe, and they all worked. Many were more flexible and more powerful than proprietary networks. There is now a six-year compatibility freeze on

MAP/TOP; all applications and improvements for the next six years will be compatible with MAP/TOP 3.0 today.

MAP 3.0 incorporates a technology called Manufacturing Message Specification (MMS). MMS is a very robust manufacturing description language (MDL) with the power to revolutionize factory floors. MMS can be described as an industrialized and networked variant of the PostScript page-description language (PDL). Whereas PostScript describes images for publishing, MMS is an MDL that describes the handling and shaping of products in manufacturing. No matter what the devices are on the factory floor, robots, machining devices, or assembly devices, and no matter which vendors made them, a product designer can interface all of them using MMS.

MMS can have potentially significant impact on manufacturing. First, TOP creates and shares design information in a multi vendor environment; MAP takes the electronic information onto the factory floor within one enhanced information stream. With MMS, the same software can drive similar industrial devices from any manufacturer. In CIM, the computer is used to design and manufacture products with machines anywhere around the world.

The use of networks in the future can be a significant change. The handful of leaders in each industry in each country will not only adopt MAP/TOP 3.0, they may also use it in building extensive private communications networks to tie together their customers and suppliers. These networks will utilize fiber optics and will be based on OSI standards. To get maximum effectiveness, the industry leaders will require that suppliers and customers adopt MAP/TOP technology.

The Air Force has developed a Product Definition Data Interface (PDDI), which is a standard format for adding parts information to CAD designs. A common encoding technique would allow better intersystem communication of design and manufacturing information. The Air Force has used PDDI to electronically transmit CAD and manufacturing data directly to the factory floors of manufacturing subcontractors. The National Institute of Standards and Technology (NIST) and the Initial Graphics Exchange Standard (IGES) organizations are working on a more universal Product Data Exchange Standard (PDES) less focused on aerospace manufacturing than PDDI.

The Air Force and major suppliers are working on an extension of PDDI - a Geometric Modeling Application Program (GMAP) - that will be sufficient to describe a part all the way through its life cycle. Design data will automatically generate test sequences, for instance, under GMAP. In addition, the DOD Computer Aided Acquisition and Logistics Support (CALS) program will substantially impact communications standards.

CONCURRENT ENGINEERING

Concurrent engineering is a systematic approach to product design that considers all the elements of the product life cycle during the design process.

The traditional development process is based on a serial approach. Design engineers complete a design and analyze it. Then, they pass the details to manufacturing engineers. Processing, routing, tool fixture design, shop floor control and quality programming steps are completed in a series prior to the start of production.

This serial process generally results in engineering change traffic well into the production phase. It also introduces penalties and limitations in that the design does not reflect the realities and constraints of the manufacturing environment resulting in expensive design changes.

The goal of Concurrent Engineering, also referred to as Concurrent Product/Process Development is to move design iterations forward in the development cycle. A multi-functional development team made up of Marketing, Engineering, Manufacturing, and Finance people looks at all of the product and process alternatives. They then simulate and model product and related process alternatives in the computer. Simulation helps develop a fundamental understanding of each alternative and allows the various functions to be involved in the design process before detailed drawings are released.

Companies must learn this new way of developing products. In the future, engineers will need to have a fundamental understanding of a broader scope of product and process development. The prototype “proof of concept” tools used on early Concurrent Engineering projects have defined a new generation of integrated tools. These tools span the spectrum of functions from Marketing to Quality while providing the engineer with a common, user-friendly interface. Relieved of the burden of learning a myriad of tool interfaces and interface quirks, the new engineer will have time to spend finding solutions to actual product and process development problems.

Mr. Del Lucas, Vice President of International Techne Group Inc. has modeled this process as shown in Figure 14-3.

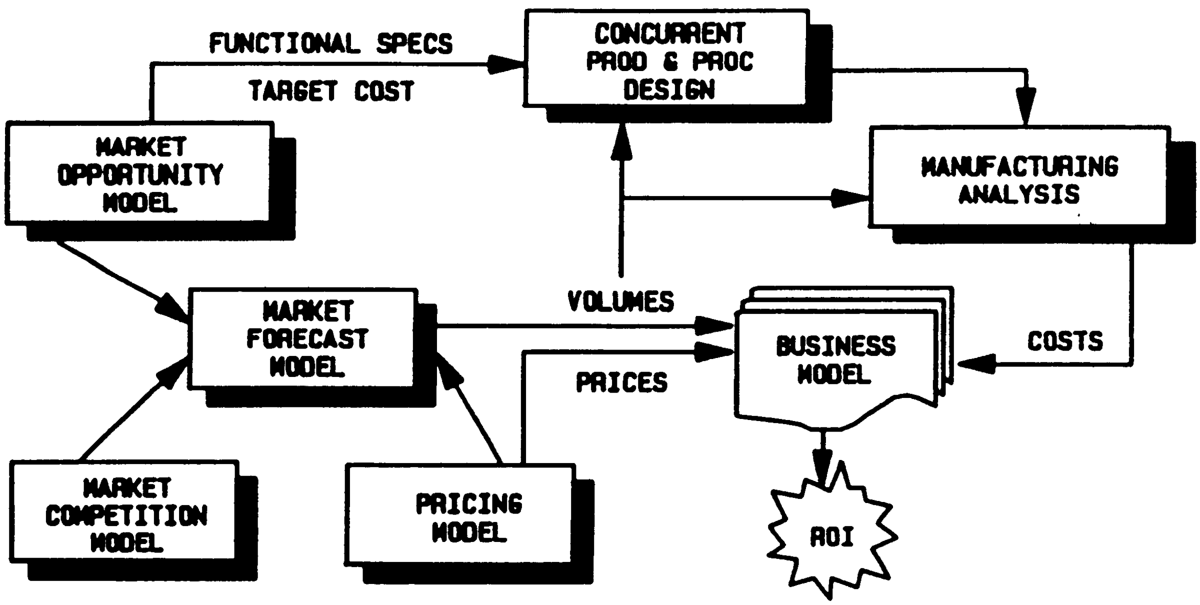

Figure 14-3 Concurrent Engineering Model

This integrated process includes:

- Developing product alternatives and then using computers to simulate them
- Developing manufacturing alternatives and the manufacturing analysis and simulation of those alternatives
- Identifying what the customer wants and how many. Will it be profitable to supply what he wants?
- The multi-functional team
- Next-generation tools

Product alternative evaluation involves the creation of concepts which are then analyzed, and simulated. Selective testing is performed to validate the simulation models. A comparison of predicted results versus requirements is made for each concept.

Process alternative methods include the creation of manufacturing and assembly concepts. Analysis and simulation of these concepts and validation of simulation models by selective testing allow comparison of predicted results vs. cost, production flexibility, and investment requirements. Each product concept is analyzed for its potential to be grouped with similar parts across families within each concept application.

Exploded views of a concept applied to a family of applications to a common scale provide a good way to scope the size range of the application family. A common type of automation which makes sense for the application family is the primary criterion for scoping the limits of rationalization.

Simulation and analysis of each product concept and each volume and automation alternative produces estimates of product costs and capital requirements. The system which must be integrated to produce the necessary simulation and analysis is shown in Figure 14-4.

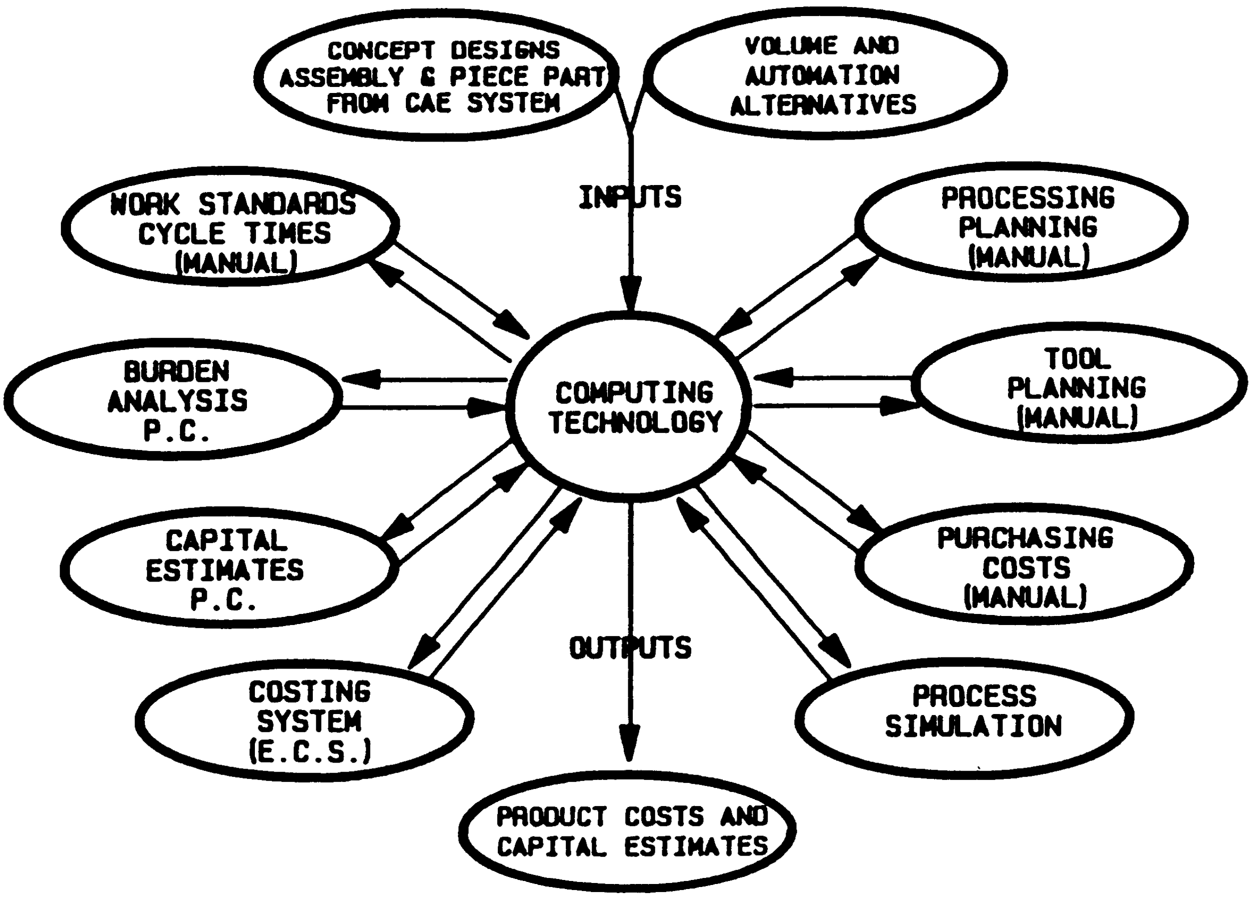

Figure 14-4 System Integration in Concurrent Engineering

Additionally for each concept, alternative CIM interfaces are considered. These include Networks and Controllers, Real-Time Scheduling and Monitoring, Support Systems, and Quality. The need for consistency with corporate systems must be considered at this stage of the development process. Supplier links to access statistical process control and other types of information, including graphics, must be included. Links to customers are an even more important consideration because different customers may dictate different types of interface needs.

The manufacturing and assembly layouts and process simulation provide the team with feedback on how relatively difficult it is to produce a given product concept alternative. They also provide an early look at the types of manufacturing and assembly automation that the product must be "designed for."

Projects using Concurrent Product/Process Development Methodology have produced very favorable results. However, these results have not been won easily. Each functional area requires its own specialist to interface with the computer aid. Even within functional area, the engineer who models on one software package may not be able to simulate a system on another software package. The two programs may interface differently and may not be "user-friendly."

With the advent of next-generation tools, interfaces between different functional models will become easier. These tools will provide a common interface to different functional models. Interface requirements of the different functional tools will be transparent to the user. As a result, users need to understand little of the mechanics of the individual functional tools. For example, an engineer can go from building a solids model to building a manufacturing cell using a "part flow analysis" model and then to finding a forecast volume niche from the market model at the same terminal. The same interface format will be used and there will be outward indication that the engineer is switching from one system to another.

COMPUTER AIDED ACQUISITION AND LOGISTICS SUPPORT

Computer Aided Acquisition and Logistics Support (CALS) is a DOD strategy to accomplish the transition form the current paper intensive design, manufacturing and support processes to a highly automated, integrated mode of operations for future weapon systems.

Objectives

The CALS program has three broad objectives as outlined in a policy memorandum by the Deputy Secretary of Defense, William H. Taft, IV, in September 1985:

- To accelerate the integration of reliability and maintainability design tools into contractor CAD systems. The payoff will be more reliable, supportable weapon systems with a lower life cycle cost.
- To encourage the automation and integration of contractor processes for generating weapon system technical information. The payoff is more consistent data, less duplication of effort, and ultimately lower data costs.
- To rapidly increase DOD capabilities to receive, store distribute, and use technical information in digital form.

The DOD and industry have established and effective organization for planning and implementing CALS. Key organizational entities and functional area assignments are depicted in Figure 14-5.

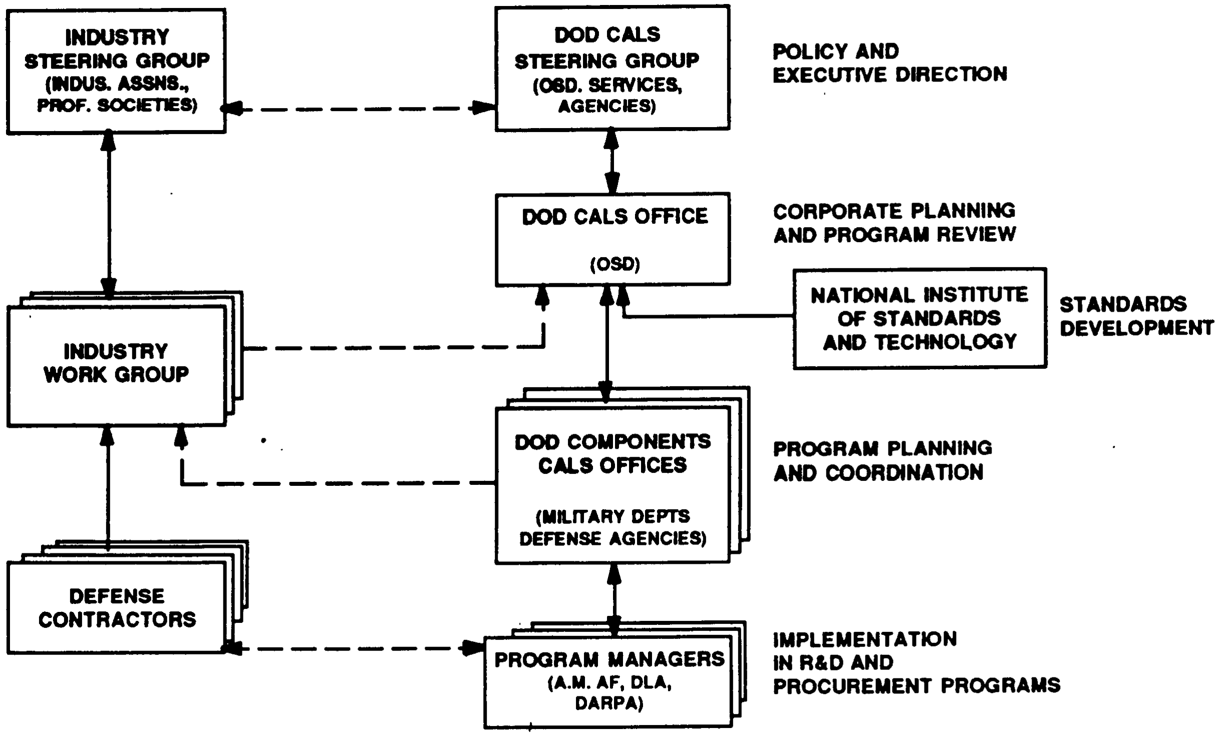

Figure 14-5 CALS Management Organization

Organization

CALS, of course, is not a system, but rather a strategy to link together a system of systems in DOD and industry to achieve the objectives and payoffs described. The target system for CALS integration is one whose primary purpose is to process (create, modify, store, distribute, or use) weapon system technical information in digital form.

Integrated Weapon System Data Base Concept

The long term goal of CALS is the development of an Integrated Weapon System Data Base (IWSDB) which incorporates digital engineering product data and logistic support data into a shared, distributed data base. The IWSDB will provide rapid availability of information to DOD Components and industry throughout the lifetime of a weapon system. The two major components of the IWSDB data base are product data and support data. Their planned transition phases and ultimate culmination in the IWSDB are illustrated in Figure 14-6. This distributed data base will support a full range of life cycle applications shown in Figure 14-7.

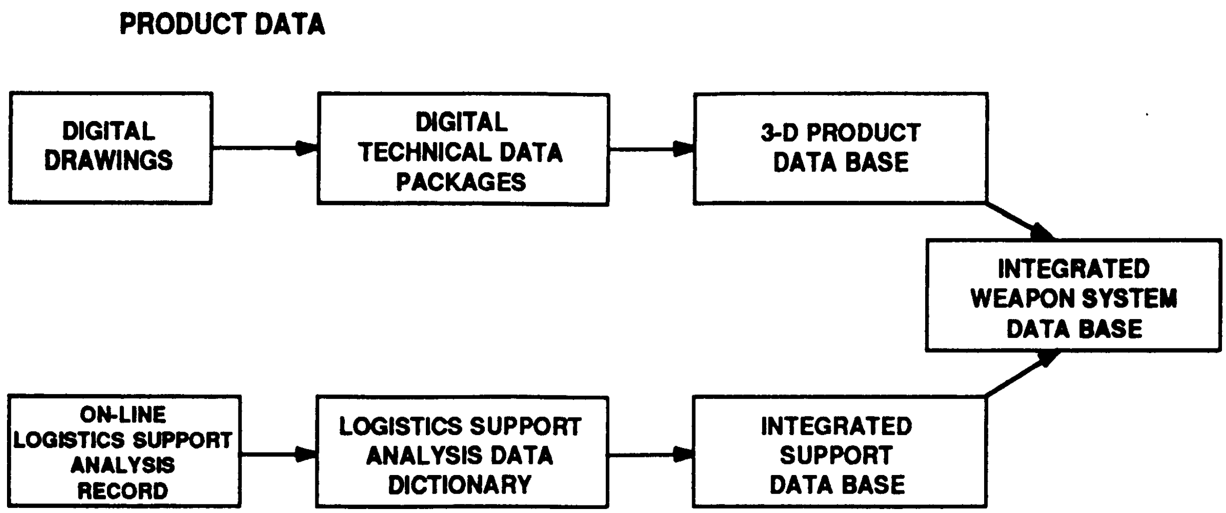

Figure 14-6 Transitional Plan for the IWSDB

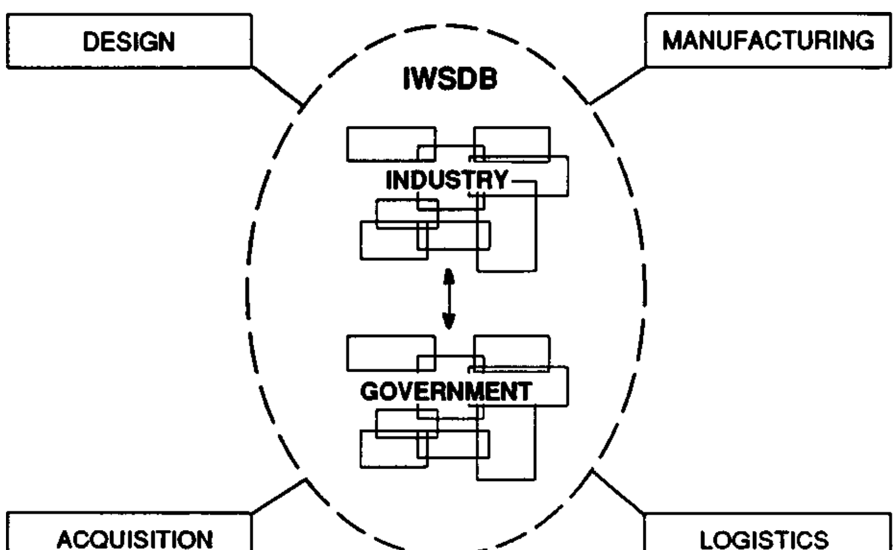

Figure 14-7 Integrated Weapon System Data Base

CALS provides a unique opportunity to achieve major productivity and quality improvements through carefully planned and managed investment by both Government and industry. As the cumulative impact of CALS implementation is experienced through the process of infrastructure modernization in DOD and industry, major savings will occur as DOD and industry incorporate more far-reaching functional changes made possible by weapon system life cycle cost, shortened acquisition times, and improvements in reliability, maintainability and readiness.

Figure 14-8 illustrates the current flow of logistics support information. While much progress has been made in CAD/CAE and CIM systems, data must still be converted to hard copy (paper, vellum, aperture cards) for use in the DOD logistics systems.

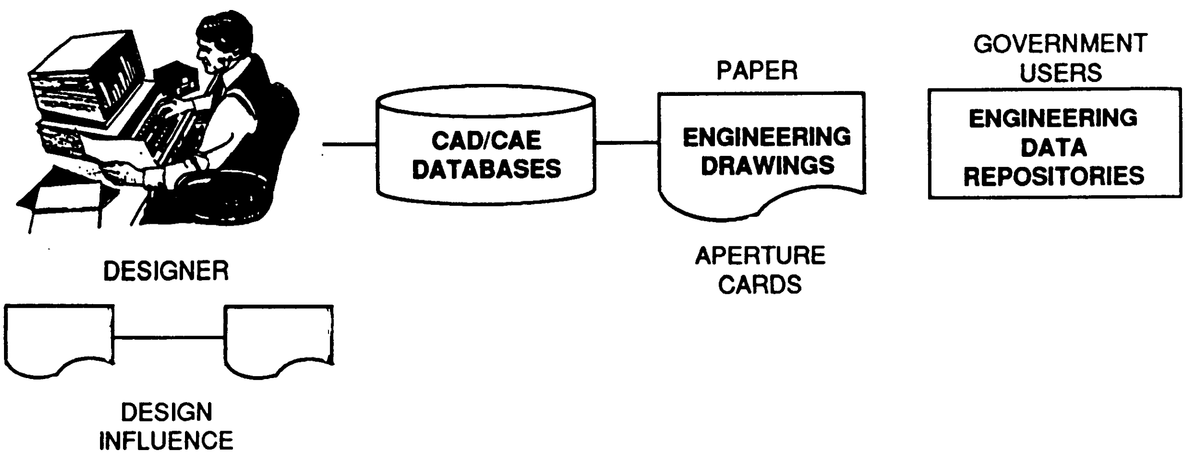

Figure 14-8 Current Data Transfer

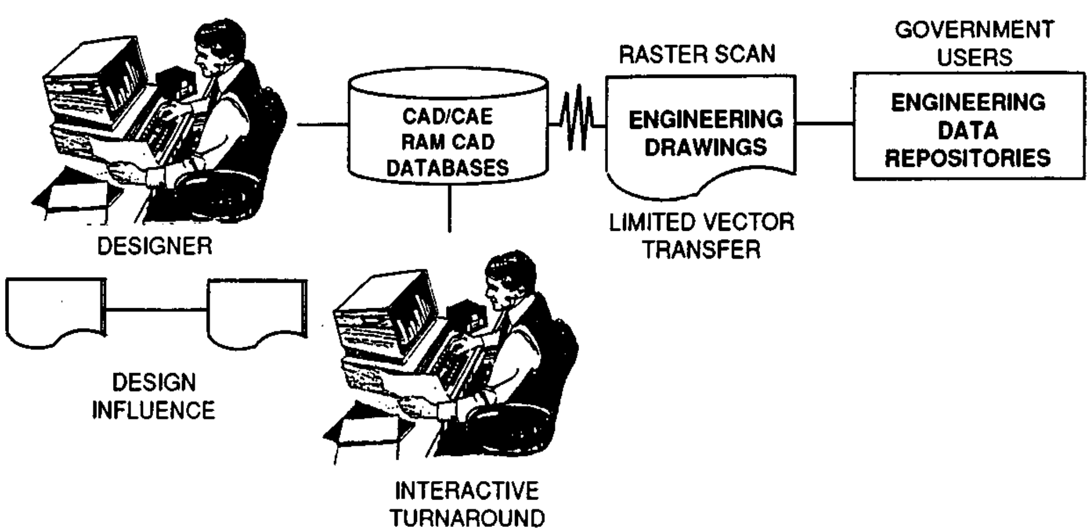

Figure 14-9 Near Term Improvements

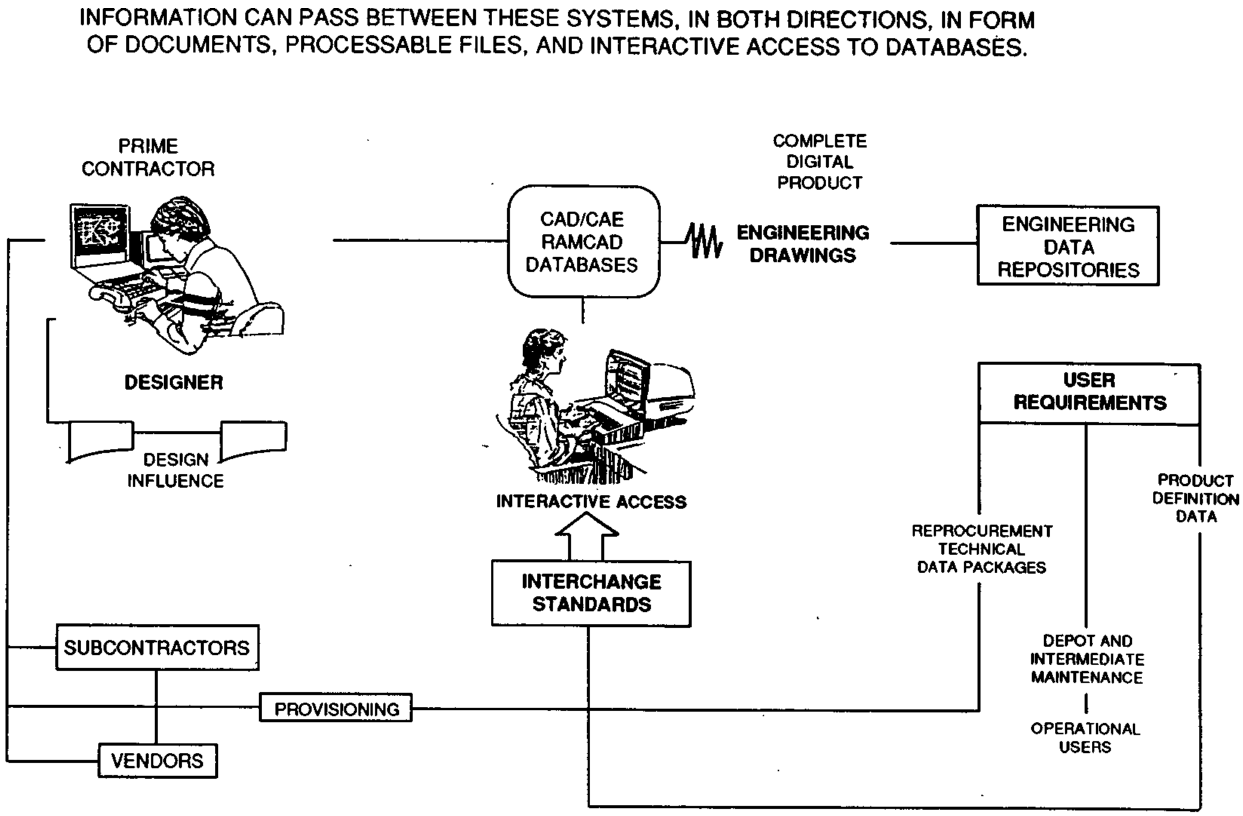

Figure 14-10 Computer-Aided Logistics Support

The evolutionary part to effective communication sought by CALS is shown in Figures 14-9 and 14-10. Already some prime contractors are starting to integrate some of their stand-alone data systems, eliminating redundant data and making timely information more accessible to users. This reduces the number of paths for data transmission to the government, thereby simplifying the translation problem. In the longer term, the goal is an environment of distributed databases connected by local area and wide area networks that provide DOD and industry users with direct access to the information they need. This scenario opens the possibility of relying on specified government access to the contractor's database rather than delivering data to a DOD repository, at least for a portion of the life cycle. The technical issues (communications, distributed database information integration. These changes represent the ultimate goal of CALS implementation and will result in a lower technology), the legal and policy issues (rights to data, security, competition), and the cultural changes (realignment of some current functions) combine to make achievement to this target system a challenging goal indeed.

The CALS program is committed to establishing a unified interface with industry for digital data exchange. The mechanism for this unified interface will be a set of private sector data exchange standards and DOD applications subsets. The same standards will be used to ensure the compatibility of systems within DOD for technical data interchange.

Due to the importance of this standardized interface, DOD has obtained the support of the National

Institute for Standards and Technology (NIST) of Gaithersburg, MD, in the selection and implementation of CALS standards. In 1987, the NIST effort is focused on developing tightly defined application subsets and compliance testing approaches in the following areas:

Product definition data. The primary standards involved are the Initial Graphics Exchange Specification IGES and the Product Data Exchange Specification (PDES). IGES will be used as a near-term mechanism for transferring data among CAD systems. Early difficulties in the completeness of transfer are being addressed by narrowly defining DOD application subsets and establishing validation tests. For the longer term, CALS will make a substantial commitment to the development of PDES. Product data is the common ground for CALS and CIM, and coordination with the CIM community will be essential.

Computer graphics. The primary data exchange standards are the International Consultative Committee for Telephone and Telegraph Group 4 raster scan standard and Computer Graphics Metafile. Also of interest to achieve device-independent graphics presentation capabilities are Computer Graphics Interface, Graphical Kernel System, and Programmers Hierarchical Interactive Graphics Standard.

Text processing. The primary near term standards in this area is Standardized Generalized Markup Language. Other standards, such as Office Document Architecture/Office Document Interchange Format, Text Composition Language, and Text Presentation Metafile, are being considered for longer-term implementation.

Database management. To support the goal of neutral access of distributed databases, CALS applications of the Information Resource Dictionary Standard, Structured Query Language, and Network Data Language are being examined.

FUTURE OF ROBOTICS

The U.S. industry and the government should foster more widespread use of industrial robots. The application of robots was one of the keys to the remarkably high levels of productivity achieved by the Japanese in the 1970’s. The Robot Institute of America (RIA) suggests that U.S. industry assign high priority to the installation of robots, especially in dangerous, dirty, and dull jobs, “recognizing that robots are one of the quickest and cheapest ways to increase productivity.” Also, industry must accept the responsibility for retraining workers who are displaced by robots. Industry managers will have to communicate with the work force and help the workers to understand the advantages of using robots. Further, industrial managers will have to develop plans so workers will share in the benefits of increased productivity.

Someone has said that “if robots are becoming the tireless arms and eyes of production, then computers are their minds.” The versatility of the computer has made it one of the principal elements leading to the automation of the factory. According to the National Institute of Standards and Technology, computer-aided design (CAD), computer-aided manufacturing (CAM) and computer-aided testing (CAT) have more potential to radically increase productivity.

The new flexible manufacturing systems in which several numerically controlled production machines are grouped, along with a transport system, under a control of a main computer, are impacting productivity substantially. Using this type of manufacturing system, machine tool utilization has increased as much as 45 percent in some companies.

Robot manufacturers have been reluctant to talk about “smart” robots - those capable of decision-making — because, for the most part, industry has only started to utilize the capabilities of existing robots. If industry’s interest in robots grows as expected, smart robots will be used in many U.S. factories in the 1990s. The smart robots will be able to understand spoken commands, or they will be able to convert printed language into operating commands. Also, the elementary intelligence available in some robot programs will be able to give the robot the ability to change a program on its own, or to modify a program to cope with a new situation. Fortunately, the more sophisticated robot designs will not make the earlier designs obsolete. The new robot designs will be capable of performing more demanding tasks, and older robots will continue to perform their previously assigned tasks.

The robots of the late 1980s and early 1990s will be more economical, reliable, and versatile (as well as programmable) than those in use today. They will continue to provide a solution to the problems that are encountered when manufacturing takes place in hazardous, unpleasant, or monotonous environment. Robot qualities and benefits will exert a positive influence on the robot market, a market that may reach $3 to $4 billion in sales by the mid-1990s, with the heaviest demands coming from the electronics, automobiles and aerospace/defense industries. Because the benefits available through the application of robots within specific ranges, industrial managers will find ways to accommodate them in the factories. Products will be designed for robot handling. Massive shifts in the nature of factory skills will be made with little, if any, loss in the work force. These events, of course, will increase the size of the market for educational robots . . . robots that tend to mimic their industrial counterparts.

Other advances in robots on the horizon are those with the following characteristics:

1. Higher speeds, better stability, and improved controls.

2. Multiple-armed configurations.

3. Off-line programming in a high-order language.

The potential advances show great promise. However, the greatest advance in robot use may come about as a result of more effective manufacturing management techniques. For example, “group technology” will be a boom to robots. This technique involves classifying parts to be manufactured into families. Parts are never placed in bins for storage or transferred to other areas. The parts maintain their orientation throughout the entire manufacturing process. In addition to group technology applications, robots will be used in CAM, product assurance systems, and automatic-warehousing.

As we prepare for the coming age of robots, it is important to keep the following points in mind. First, the initial cost and possible benefits of using robots may be difficult to establish. Second, there may be surprises and setbacks along the way. Third, a structured environment and thoughtful approach to robot applications will usually ensure success.

Forward-looking industrial managers recognize that the introduction of robots will bring about major changes in manufacturing operations. These managers are looking beyond the simple one-for-one replacement of workers and toward understanding the interactions within the manufacturing operations so they can identify those applications where robots can be applied successfully. Further, these forward-looking managers are calling for a systems approach to conceive, define, and build robotic cells. Such an approach will ensure that three goals for successful manufacturing operations efficiency, flexibility, and effectiveness will be met.

Robotic technology will be integrated into flexible manufacturing systems. In the production of products, there will be a movement back to the concept of a general purpose robot with many human-like attributes. In the final analysis, robots will continue to present industrial management with a tremendous challenge. The industrial firms in which management meets the challenge successfully will prosper; the firms in which management fails to meet the challenge head-on may fall by the wayside.